Air Force Develops Environmentally Friendly Oxygen Line Cleaning System

Avoids the Use of Ozone Depleting Chemicals and Saves Money

The Air Force has led a Joint Services effort to develop an in place oxygen system line cleaner that can clean the entire oxygen plumbing system without requiring the removal of components or lines. The system is environmentally friendly and easy to use.

The OLCS cleaning a Kentucky Air National Guard C-130 in Louisville, Kentucky (6 June 2002).

Background

In the mid 1990's, Air Force oxygen systems engineers at Tinker Air Force Base (AFB) began studying the possibility of new technologies that would enhance the oxygen systems cleaning arena. Aircraft oxygen systems have been maintained in the same manner since the post World War II era. Additionally, the chemicals used to clean oxygen system lines and components were deemed environmental hazards and have become outlawed, or production has ceased. The engineers were certain that a better method could be devised to clean oxygen systems and components, as well as validate the cleanliness of the components once cleaned. This was a new concept, since no current cleaning methods validated cleanliness. They were merely best practices for the industry using a known solvent, primarily CFC-113 (freon).

In early 1999, the oxygen engineers secured funding from the Environmental Security Technology Certification Program (ESTCP) and teamed with consultants from Versar Inc. to develop a prototype Oxygen Line Cleaning System (OLCS) that could clean intact aircraft oxygen lines - essentially cleaning the entire plumbing system without requiring

The OLCS cleaning an F-16 at the Tulsa Air National Guard Base in Tulsa, Oklahoma.

the removal of lines or components. Later that year, the Joint Group on Pollution Prevention (JGPP) assumed management of the project, provided additional funding and expanded the project across the Joint Services to target the elimination or reduction of Ozone Depleting Chemicals (ODC) in the military.

The project partnered with the National Aeronautics and Space Administration (NASA) and the Navy to develop a Joint Test Protocol to ensure that all critical test criteria were identified, and that the new system would meet or exceed the requirement of current military specifications, Technical Order (TO) and American Society for Testing and Materials (ASTM) requirements.

OLCS Method for Cleaning Aircraft Oxygen Lines

The OLCS method for cleaning aircraft oxygen lines is performed by a fully automated trailer mounted machine, that is computer controlled via a touch screen monitor. The OLCS is positioned and connected to the system to be cleaned at an in-flow point (generally adjacent to the oxygen source). A return line is connected at an out-flow point(s) (generally just before the oxygen regulators at the crew positions). In the event of numerous out-flow points (such as an aircraft with multiple crew positions). Each flow path can be cleaned utilizing a computer-controlled manifold to control the solvent flow sequence.

The basic cleaning procedure consists of the following four phases:

1. System Test,
2. Wash and Rinse,
3. Cleanliness Verification, and
4. Solvent Removal and Verification.

Phase 1—System Test

The initial phase of the precision cleaning process, or System Test, is a leak test performed by pressurizing the system with dry air to ensure that no solvent loss will occur once the system wash cycle is initiated. If a leak in the system is detected, the OLCS will alert the operator to correct the condition. Also, during system test, a vacuum is pulled on the system to ensure that no soft tubing or rubber hoses will collapse. (A vacuum is used to remove solvent from the system after cleaning.)

Current Process for CLEANING AIRCRAFT OXYGEN LINES

The current process for cleaning aircraft oxygen lines is a manual, labor-intensive effort that requires considerable time and expense. If a section of an oxygen line requires repair, replacement or cleaning, other components within the aircraft must be disassembled so that the oxygen line can be accessed, removed at the end fittings and remanufactured.

Once the metal bending and cutting is done, the line is cleaned with CFC-113, either by aerosol spray or bulk solvent placed in the line and shaken side to side. The lines are considered “clean” when the effluent stream is free from contamination – which offers no indication of the contamination remaining in these lines. Also, the waste solvent is vented directly to the atmosphere.

The ends of the lines are then double bagged until they can be reinstalled on the aircraft. Teflon tape is used on the end fitting to help prevent leakage once reconnected. If the aircraft oxygen system becomes contaminated, the entire plumbing system must be removed and cleaned in the above-mentioned manner. After the lines are reinstalled, the system undergoes a hot gas purge for approximately two hours.

This entire cleaning process requires considerable time, effort and cost, and is environmentally unsound.

In the past few years, several B-1B bomber aircraft had to have their entire oxygen systems cleaned. It has been reported that the cost exceeded $1M per aircraft and utilized approximately 15 gallons of CFC-113 per aircraft. Once re-assembled, extensive aircraft systems checkouts had to be accomplished since nearly every other system onboard the aircraft had been disturbed during the process. The entire process took several months to accomplish during which the aircraft is out of service.

■ Phase 2—Wash and Rinse

Once leaks are eliminated, HFE-7100TM solvent is slowly pumped into the system. The pressure is gradually increased to attain a specified flow rate through the lines. The flow stream is circulated through a 2-micron filter to remove particulate contamination. After the wash period is completed, a fresh supply of HFE-7100 TM is pumped through the lines as part of the pure rinsing process. This rinsing removes any remaining particulate contamination as well as non-volatile residue inside the oxygen lines.

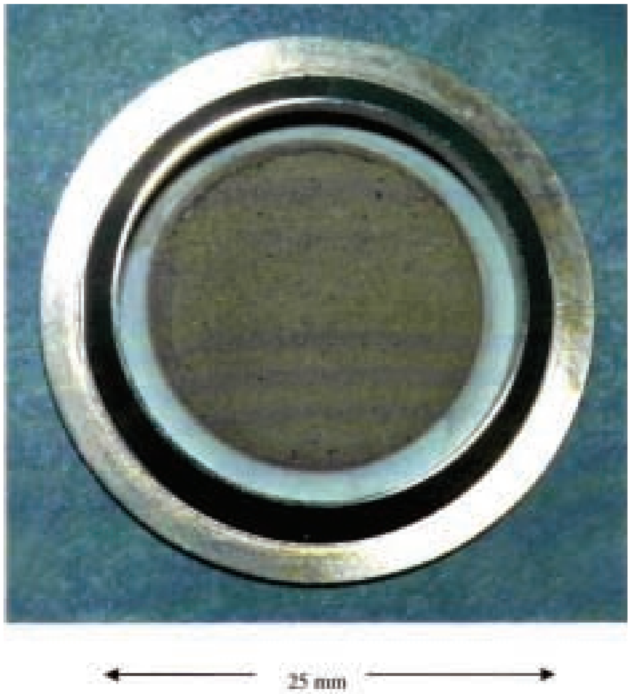
■ Phase 3—Cleanliness Verification

During this phase, the HFE-7100 TM rinse stream is analyzed by particle counters, which incorporate laser diode technology. The particle counter measures 10 particle size distributions in the effluent stream ranging from two to 500 microns. If the sensors continue to detect unacceptable particulate matter, the OLCS will continue to operate until the specified cleanliness level is achieved.

■ Phase 4—Solvent Removal and Verification

Once the desired cleanliness levels are reached, the OLCS will pull a vacuum on the system to a level low enough to bring the HFE-7100 TM to a boil. This creates an atmosphere where the solvent can no longer exist in liquid form. Once the vacuum cycle is complete, the OLCS will initiate a dry air purge to remove any remaining solvent in the oxygen flow path. Halide detectors are utilized in the exit air stream to verify that the solvent has been removed. The initial control limit on solvent removal was 40 parts per million (ppm); however, during testing levels down to 5 ppm were achieved. The entire process can be observed on the touch screen monitor.

At this point, the cleaning process is complete. The OLCS is disconnected and removed from the area. The OLCS contains a solvent distillation unit onboard. All solvent used during the cleaning process is

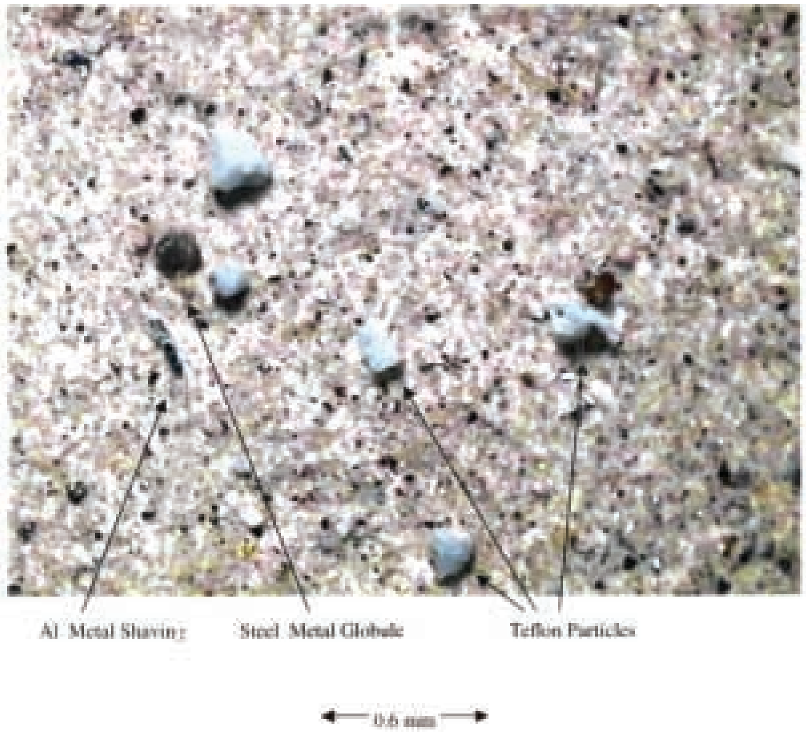


This is a 40-times magnification of the filter patch. Note the cake of contaminants from a presumed clean aircraft system. Much larger pieces were also extracted that were easily visible to the naked eye.

CHOICE OF HFE-7100™ CLEANING SOLVENT

The project team selected HFE-7100™ (a HydroFlouroEther manufactured by Minnesota Mining and Manufacturing Company (3M), a Novec™ fluid) as the OLCS cleaning solvent because they wanted to avoid aqueous solutions for onboard aircraft. Any risk of residual fluid could result in the possible freezing and bursting of oxygen lines at high altitudes. The project team also wanted an environmentally safe solvent that provided the safest threshold for use in human breathing systems.

The OLCS can be considered for use on other non-human plumbing systems and can incorporate the use of more aggressive solvents if necessary. Plans are currently planning underway to test the system with a second, more aggressive solvent - AK-225g. NASA is setting up a demonstration for evaluating the use of the OLCS to clean its rocket engine test stands. As with any new chemical, compatibility issues and testing are required to validate its effectiveness.



Similar contaminants were found in all aircraft that were cleaned. This is a photo of a 25mm filter patch with some of the contaminants extracted from the C-130 oxygen fill system. The contaminants include silicon, metal cuttings (brass, aluminum, stainless steel), high chrome steel (melted), Teflon, a plastic rubbery substance and red dirt believed to be iron oxide.

distilled and collected in the solvent storage tank ready for the next cleaning application.

Results of OLCS Testing

The OLCS testing established several benefits that could be achieved through implementation of the system. The initial benefit is the reduction or elimination of hazardous solvents in the cleaning of oxygen systems. The OLCS cleans with an environmentally friendly solvent, recaptures and distills it for future cleanings. Secondly, the OLCS can reduce Operation and Maintenance (O& M) costs for weapons systems. A conservative estimate by the oxygen system engineers is that the Air Force could realize over $1M savings annually in oxygen regulator overhaul due to particulate contamination in oxygen systems. Further savings would be realized by decreasing current failure rates of other oxygen system components. A third and substantial benefit, is that the OLCS can save the Air Force over $1M per occurrence cleaning an entire aircraft with a contaminated system, as has happened on the B-1B and T-6 aircraft. It is doubtful if all oxygen lines can be accessed for removal on most aircraft. Contaminated systems currently require complete dismantling of the system lines and components, then manually cleaning each piece by open spraying of CFC-113. That procedure takes one to three months to accomplish on a B-1B, requires extensive man hours to complete, then requires extensive systems check outs since nearly every functional system on the aircraft is disturbed during the cleaning process.

Extensive testing has been carried out during the life of the project, and demonstration/validation procedures were conducted on the B-1B, F-15, F-16 and C-130 weapon systems. After four years, the demonstration validation program has come to its conclusion and has proven to be very successful in achieving its intended goals. The new tasks at hand, as outlined by ESTCP and JGPP, are to transition and implement the new technology into aircraft production and overhaul facilities. The project has resulted in a fully functional prototype OLCS at Tinker AFB, Oklahoma and the unit is ready for use.

Further information regarding the project can be seen at www.jgpp.com. The web site contains copies of the Joint Test Protocol and the Joint Test Report. Additionally, contact the Air Force Program Manager, Jerry Gore, Oklahoma City - Air Logistics Center, Tinker AFB, or John Herrington, Versar Inc.

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